Wind and solar power are two of the world’s fastest-growing renewable energy resources. However, forecasting errors and intermittency pose challenges to system operators and limit the use of wind and solar as reserve products. This project developed a stochastic optimization model to determine the optimal offer strategies for wind and solar producers that participate in the day-ahead (DA) and real-time (RT) markets and offer energy and reserve products, including spinning reserves, up regulation, and down regulation. The cost function maximizes the total expected profit while minimizing risk by splitting day-ahead offers between the energy and ancillary service markets. Model outputs include the expected profit in each market in the DA and RT stages and offer curves for each of the four possible products. Case studies are used to verify the model’s effectiveness.

**Motivation**

Wind and solar resources are currently ineligible to provide ancillary services in US electricity markets, due to their intermittency and high forecast uncertainty. However, to increase the share of energy provided by wind and solar, it may be necessary to use these resources to provide system reserves. Since forecasting errors and intermittency currently limit the use of renewable resources, stochastic optimization, which can consider many different forecast scenarios and formulate an optimal offer given all possible scenarios, is an appropriate tool for calculating optimal energy and reserve offers for renewables. Uncertainty in market prices may affect the producer’s offers and should be considered as well. Finally, the risk-aversion level of the producer may impact the offer strategy and should be considered as well.

**Case Study**

Case studies for wind and solar power are performed to verify the effectiveness of the proposed model. Historical data for generating the price scenarios is obtained from the Southwest Power Pool (SPP) database [3]-[4]. Historical data for wind and solar are obtained from the National Renewable Energy Lab (NREL) databases [5]-[6]. Four months are analyzed to study the impact of seasonal differences on the bidding strategy. The wind and solar producers in the study have capacities of 2 MW and 6 WM, respectively. The weight on the CVAR term $\beta$ is set to 0.1, and the CVAR quantile $\alpha$ is set to 0.95. Fig. 1 shows offer curves generated by the model. Fig. 2 shows the CVAR for wind and solar for each month tested. Higher CVAR corresponds to higher profit in the worst-case scenario, indicating that June and December are expected to be the most profitable months for wind and solar, respectively. Fig. 3 shows the expected profit by product for solar power, while Fig. 4 shows the same for wind power.

**Conclusions**

Results of the case study show that most profits come from offering DA/RT energy products. Regulation products are offered occasionally, with the most up and down regulation combined offered in March for both wind and solar. Spinning reserves are rarely offered and could likely be eliminated from future models with minimal change in expected profit. Spinning reserve prices are often the lowest in the DA and RT markets out of the four product types, so it is expected that the wind/solar producer would rarely choose to offer spinning reserves.

The model developed through this project could be useful for public utilities with wind and solar facilities, but limited resources for developing their own bidding models.

**References**


